FOSSIL MAMMALS OF THE COIMADAI LOCAL FAUNA NEAR BACCHUS MARSH, VICTORIA

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Turnbull, W.D., Lundelius, E.L., Jr. and Tedford, R.H. 1990 3 31: Fossil Mammals of the Coimadai Local Fauna near Bacchus Marsh, Victoria. *Mem. Qd Mus.* 28(1): 223–245. Brisbane ISSN 0079–8835.

De Vis (1898) first published on Coimadai fossil vertebrate specimens, recognizing vombatids, macropodids and diprotodontids. His identifications are updated, and specimens recovered since de Vis' day are assessed. The locality, which is now partly submerged by the waters of the Marrimu Reservoir, appears to be early Pliocene in age. The hardest, normally most resistant, calcified tissues were destroyed preferentially, apparently by solution. The geological and stratigraphical evidence for a pre-Bullengarook Pliocene age of relationship of the sediments (including Coimadai Limestone) to the Rowsley-Fault, and on the eruption of Mt Bullengarook Of the seven post-Miocene genera, five are extinct (*Kurrabi, Protemnodon, Troposodon, Euowenia* and *Zygomaturus*), and two have species living today (*Vombatus* and *Macropus*)
☐ *Victoria, Pliocene, Marsupials, Taphonomy.*

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Ninety years ago, de Vis, (in Appendix A to Officer & Hogg 1898), reported a sample of 22 fossil marsupials from lacustrine (usually dolomitic) and fluviatile limestones at Coimadai, Victoria that had been collected by Officer, Hogg and Ferguson of the Victoria Mines Department. Other specimens reported here were collected incidental to the quarry operations of the late 19th and early 20th centuries. We report on all of the material from the various Coimadai quarries which are in the collections of Melbourne University Geology Department (MUGD), the Victoria Mines Department (VMD) and the Museum of Victoria (NMV). The VMD materials are now incorporated into the NMV collection (nos P186781-186806). Opportunity for collecting additional materials is nil, the quarries having been nearly exhausted, and the remnants of the formation are now submerged by Lake Merrimu, one of several reservoirs in the Warribee drainage. In addition to reporting on the fossils, we describe the locality in so far as is possible at this late date, using photographs taken by two of us (WDT & ELL) in 1963-4. The locality, about 10 km NNE of Bacchus Marsh, is in the valley of Pyrete (Coimadai) Creek, a tributary of the Warribee River. It is about 3 km E of the Rowsley Fault, the major N-S fault in the area which was active in the Early Pliocene (Gill, 1964). Coulson's (1924) map shows three of the quarries immediately S and E of a much smaller fault, the E-W trending Coimadai Fault of Fenner (1918). The map provided by Officer and Hogg (1898) covers a larger area N-S, and shows the path of the Lava tongue from Mt Bullengarook (12 km to the N) that filled the former Bullengarook Creek (or River) valley with a resistant basalt. Subsequent drainage was thus diverted to the E and W sides of the former creek to form Pyrete and Goodman's Creeks (Officer & Hogg, 1898, Sec. V). Their map also shows the straight E-W trending southern margin of the N block of the Ordovician sandstone (labelled Silurian by Officer & Hogg, 1898) that is part of the evidence for the Coimadai Fault (Hart, 1908; Fenner, 1918). The unnamed quarry shown by Officer and Hogg (1898) is probably Alkemade's Quarry to judge by its position. We have modified Coulson's map (Fig. 1) to show these features. For reasons given later, the limestones mapped as Pleistocene by Coulson, the same quarried limestones that produced the fossils, are most likely Pliocene in age.

There is some confusion about the quarries that we cannot resolve. The three shown on Coulson's 1924 map (and Fig. 1), Alkemade's, Hjorth's and Burnip's, are the only ones with precisely known locations, if he has not erred. Bennett's and Davies' are mentioned by Officer and Hogg (1897) and Gill (1964) respectively, without indication of exact location. Another problem is that Officer and Hogg (1897) mentioned (but did not designate) two

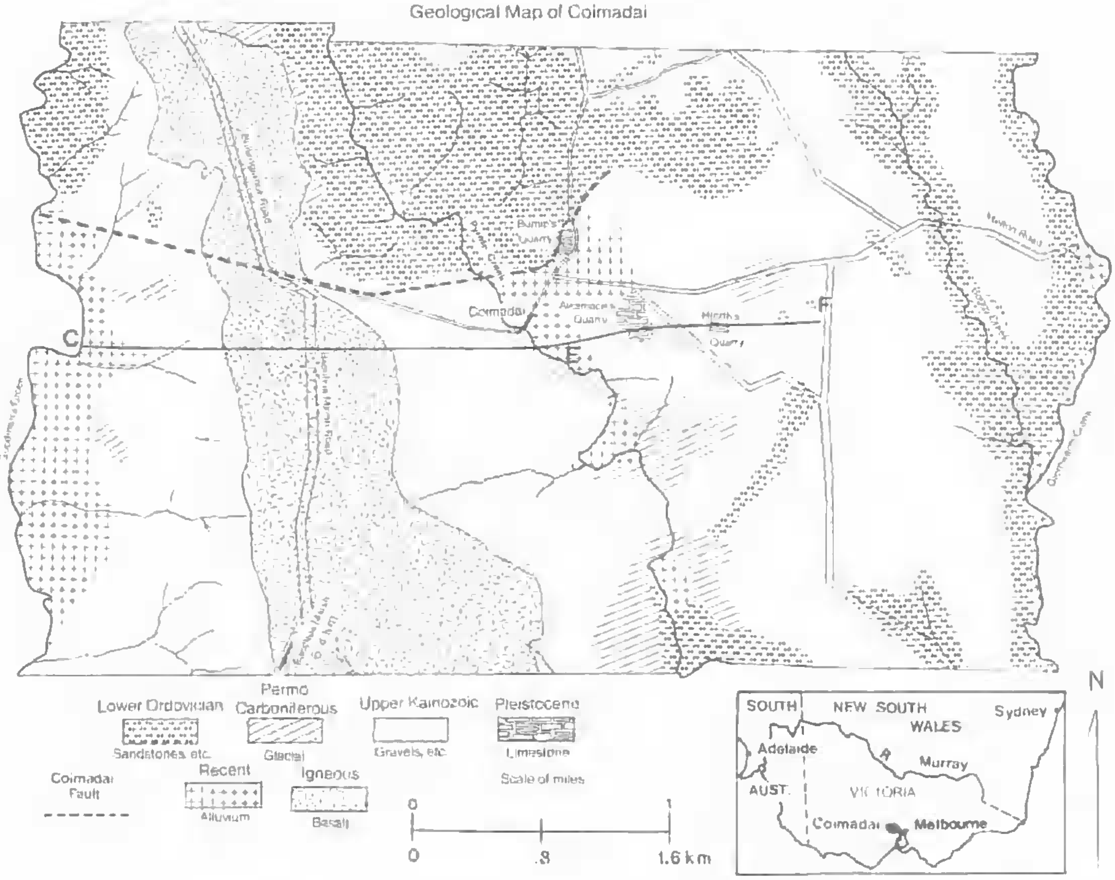

FIG. 1. Coulson's (1924) geologic map of the Coimadai area slightly modified, showing three of the quarries, the Coimadai Fault, the Bullengarook Basalt Flow within the channel of the ancient Bullengarook Creek and the modern drainages.

large quarries, Alkemade's and Bennett's, "on the eastern side of Pyrite Valley", and they go on to say, "a third and smaller quarry (Birnip's)" [spelled Burnip's on Coulson's map where the three are labelled] is "on the west side of the valley". All are on the E side of the valley. In as much as his study relied heavily on Officer and Hogg (1897-8) and followed theirs by a quarter century, we tend to accept the detail given by Coulson. In addition to this confusion, or perhaps because of it, we either misunderstood or were misinformed as to the identity of Burnip's and Hjorth's quarries when Edmund Gill showed us the locality in 1963. Our notes show the two reversed. Whichever is correct, the Alkemade quarry is by far the most important, having produced the majority of the specimens and there does not seem to be any doubt about its location. Figures 2 and 3A show the Alkemade quarry. Figure 3B shows the remnant of Burnip's, and Figure 4 gives two views of the Hjorth quarry; all show conditions as of 1964.

STRATIGRAPHY AND GEOLOGY

Since the earliest studies by Ferguson (1894) and Officer and Hogg (1897-8), the geology at the Coimadai quarries has been reported by several workers including Summers (1923) and Keble (1925). Uncertainties still remain as to interpretation of the geology and the timing of some events. Officer and Hogg (1897) distinguished five "formations" in the district: (1) Silurian [Ordovician in most subsequent works]; (2) Permo-Carboniferous Glacial beds; (3) Coimadai limestones, gravels, conglomerates, etc.; (4) Newer Basalt; (5) Post-Tertiary and Recent beds. Of these, items (3) and (4) concern us here.

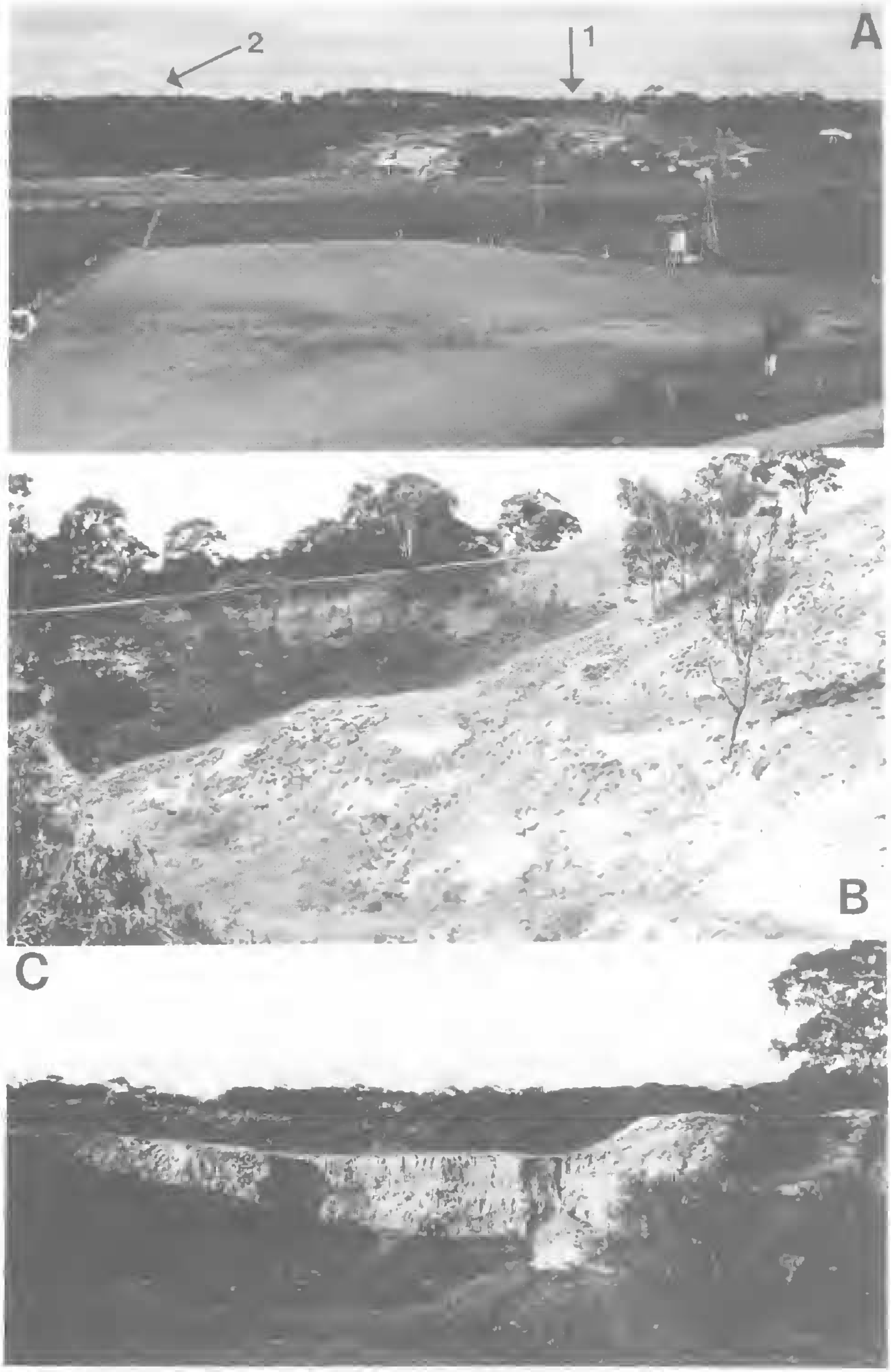

FIG. 2. Three views of Alkemade's Quarry. A, as seen from Burnip's Quarry, looking SE; arrow -1 points to Alkemade's Quarry, arrow -2 to approximate site of Hjorth's Quarry, hidden by trees. B, C, views within the quarry; the old working-face is in the distance, with mixture of overburden and rubble in middle and foreground.

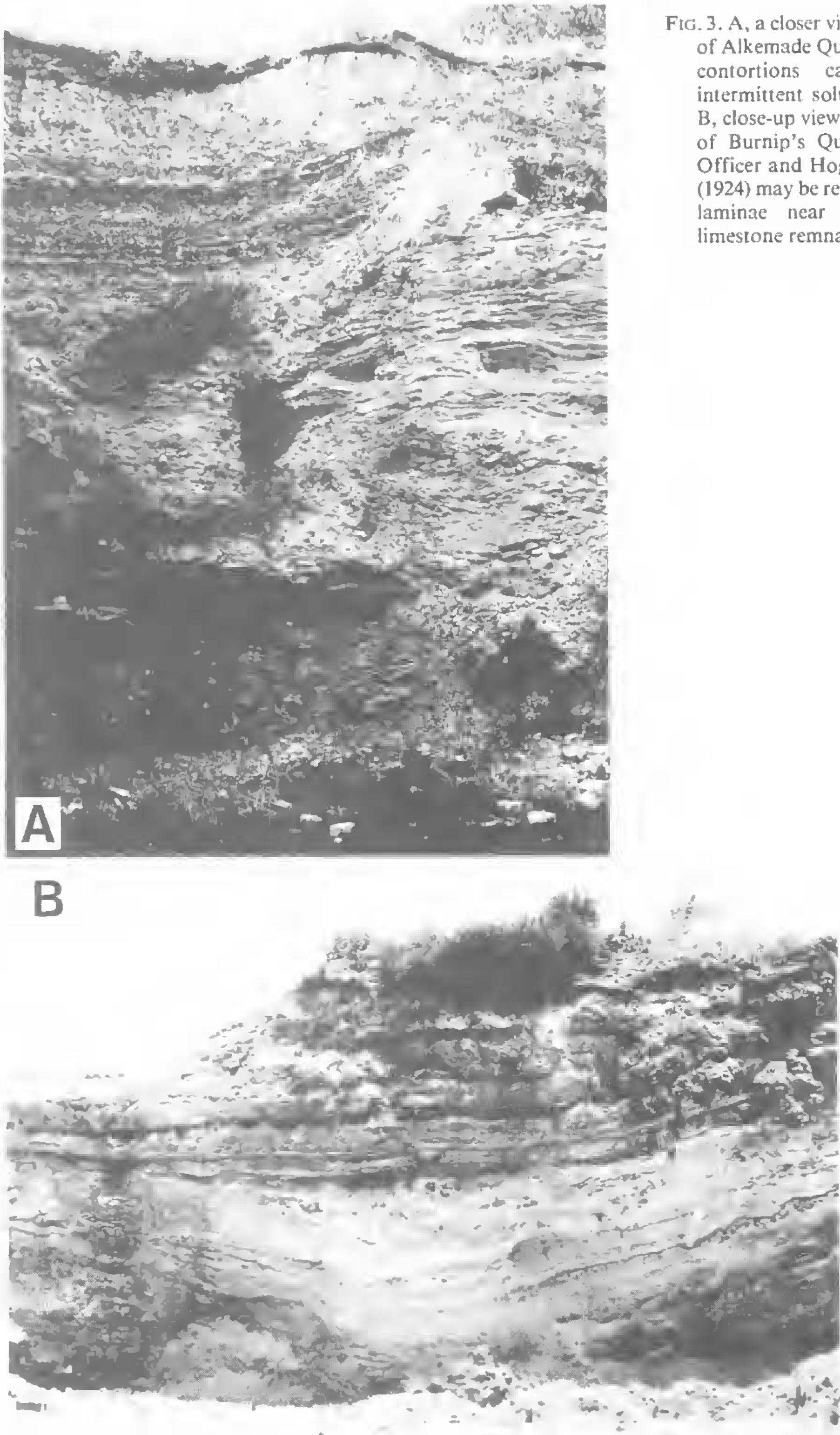

FIG. 3. A, a closer view of old working-face of Alkemade Quarry, showing bedding contortions caused by irregular, intermittent solution- collapse events. B, close-up view of face at the remnant of Burnip's Quarry; the ash bed of Officer and Hogg (1898) and Coulson (1924) may be represented by one of the laminae near the middle of this limestone remnant

FIG. 4. A, face of the small Hjorth Quarry, from the nearest point permitting the entire face to be included. B, a closer view showing bedding irregularities; according to Officer and Hogg, the ash bed was observed in this quarry too, but it was not identified in this study (perhaps covered by slump). Scale indicated by Marsh pick with 51 cm handle.

It is difficult to see close parallels between the 13.5 m (44 ft) section of Officer and Hogg (1897) and Gill's (1964) 11 m (36 ft) one measured in 1958, wherein he proposed names for the formations he recognized — Alkemade Siltstone (above) and Coimadai Dolomite. Erosion, slump and other changes during the 60 intervening years, coupled with the fact that the measurements were taken at quite different places within Alkemade's quarry, surely account for the lack of close correspondence. Most curious is the lack of mention by any worker other than Coulson (1924) of the 15 cm (6 inch) volcanic ash marker-bed 4 of Officer and Hogg (1897). Coulson noted its presence, giving mineralogical details. In their section Officer and Hogg (1898) indicate that most mammalian bones came from a 1 m (3 ft) unit of calcareous sand situated 2 m - 3 m (7-10 ft) below the ash, and in their section V (DEF on their map) the letter (a) keys the "thin bed of volcanic ash interstratified with limestone containing Marsupial bones". Two other geological problems concern the two faults. Gill's observation (1964) regarding the timing of activity of the Rowsley Fault as, "epi-Timboon Terrain (Lower Pliocene)" fits well with his notion that the deposits at Coimadai (and elsewhere E of the fault) began as alluvial fans that were generated by rejuvenation of the drainages of the upthrown western block. This in turn caused overloading of the drainages of the downthrown block (including Bullengarook Creek) causing them to aggrade. Levees and shallows developed in the aggrading parts of the Bullengarook flood-plain, and the shallows formed the lake(s) within which deposition of the limestones, limey muds and silts took place. The valley of concern was that of the ancient Bullengarook Creek, not Coimadai Creek, as Gill had stated (1964, p. 351). Then the Bullengarook lava flow filled the youngest, highest channel and thus ended that stream's existence, causing the twin streams to form. Gill (1964) did observe that the Bullengarook lava, "is higher than the deposits in the valley".

The Coimadai Fault also would have contributed to the overloading of the drainage to the S of the fault in the Coimadai area. However, in a footnote to his brief statement rejecting Fenner's (1981) explanation of the formation of the Coimadai lake "by the Bullengarook lava flow blocking the drainage", Gill (1964) questioned the existence of the Coimadai Fault, stating "The Coimadai Fault of Fenner (1918) probably does not exist since the platform cut on the Ordovician bedrock is at similar elevations on the N. and S. sides of the Coimadai valley". But he gave no topographic data to substantiate this, and by itself the point seems inadequate for rejecting the fault's existence. Coulson (1924) realized that the basaltic lava flows followed some sedimentation in the lake but was "preceded by the outburst of fine ash which was only preserved in the limestone lake". He appears to have been the first to point out the probable connection of the two features to the same event (Bullengarook eruption) although his dating of the beds as Pleistocene differs from Gill's and ours as (post-earliest) Pliocene. By drawing upon these observations of Coulson (1924) and Gill (1964), it now appears that Officer and Hogg (1893) may have provided the most informative geological summary with their schematic Section V, redrawn here (as Fig. 5) to trace a nearly E-W line located near to, but mostly just S of, the Coimadai fault,

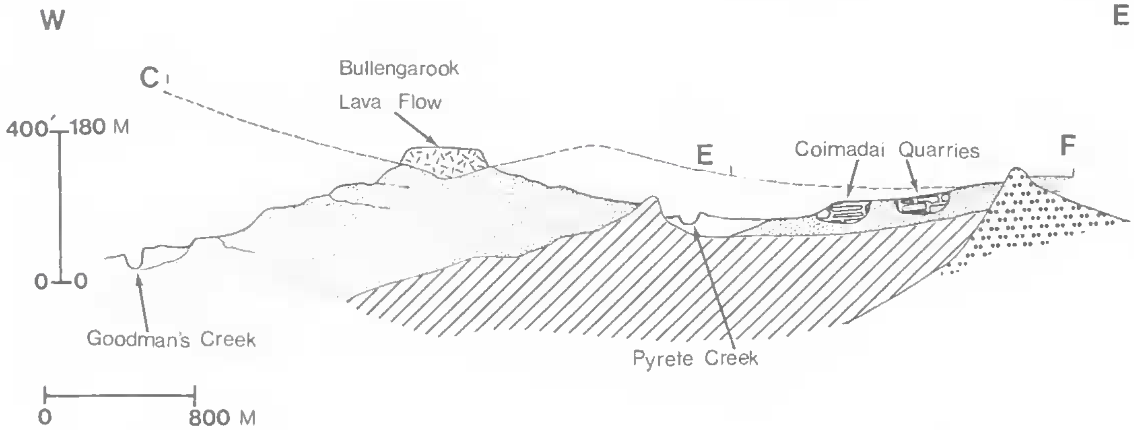

FIG. 5. Schematic section based on the Officer and Hogg (1898) map and their sections I and V, of the Coimadai area. It follows a line from about their point C to E and on to F. Geological symbols as in Fig. 1.

from their point C to points E and F. The section shows the modern streams (Goodman's and Pyrete Creeks), the Pliocene alluvial fan deposits and related fluviatile and lacustrine beds (Coimadai Limestone, including the Alkemade Siltstone and Coimadai Dolomite), the Coimadai quarries and the basalt-filled channel of the ancient Bullengarook Creek, with a suggested probable surface topography of that period (dashed lines). Two radiometric dates have been reported for the Bullengarook basalt, 3.31 and 3.64 Ma (two determinations, P. Roberts, pers. comm. to RHT, 1983). Thus the Coimadai local fauna dates from about that time since most of the bones came from just below the thin ash bed that Coulson correlated with the Mt Bullengarook eruption. Additional evidence supporting this interpretation comes from the maps of Coulson and of Officer and Hogg, wherein it can be seen that the lower area to the S of the Coimadai Fault captured much more of the post-Rowsley alluvial fan and related Upper Cainozoic (Pliocene) deposits than did the erosional upstream area to the N of that fault.

SYSTEMATIC PALAEONTOLOGY

De Vis (1898) considered that three marsupial families are represented in the Coimadai materials. This study, using additional material and benefiting from modern preparation of all the material, supports de Vis' conclusion and refines the identifications. Many specimens were preserved as vugs which were prepared by injecting epoxy resin to form artificial casts of the bones.

Class MAMMALIA
Subclass THERIA
Infraclass METATHERIA (MARSUPIALIA)
Order DIPROTODONTA
Family VOMBATIDAE

Apparently two taxa of wombats were present at Coimadai. The following materials are assigned to the family — (MUGD 1671, 3570, 3585, NMV P23219) probably to *Vombatus*, but specific assignment is uncertain.

MUGD 1671 is the right ramus with full dentition that de Vis had assigned to *Phascolomys parvus* (Owen, 1871), a taxon never widely accepted (Dawson, 1983). It persisted until Merrilees (1967) carefully examined the matter and rejected it as valid taxon. He synonymized *P. parvus* with *Vombatus hirsutus*, considering it to be a juvenile of the modern taxon. Merrilees demonstrated the unusual degree of variation in dental size that accompanies developmental stages in wombats. More recently, Wilkinson (1978) strongly supported this stance. However, we note here, for the first time, one feature not previously considered which suggests that Merrilees' conclusion may need to be altered. The Coimadai jaw, which is well within the size range of juveniles of *V. hirsutus*, has the typical form of modern adult wombats; it is swollen throughout the length of the horizontal ramus, and the ventral margin is smoothly curved (Fig. 6A). This is an important point, for in one very young modern specimen of *V. hirsutus* (FMNH 123652), the ventral margin of the jaw is extremely thin beneath each forming cheek tooth (perforate in one spot) and decidedly uneven, giving a hummocky appearance all along that margin of the ramus (Fig. 6B). The Coimadai jaw is slightly smaller overall than that of this very young juvenile *V. hirsutus* although its cheek teeth are slightly larger. In marked contrast, because there has been some minor damage to the fossil, one can see that the bone of its ventral margin is thick and has a well-developed, multi-layered compacta structure, an indication of some age and not of a juvenile condition. An X-ray (Fig. 6E) of the juvenile specimen clearly shows the bases of the forming, very hypsodont, teeth to be in close contact with the bone of the ventral jaw margin. This results in the thinning of the bone in the immediate area of each developing tooth and in bulging these regions out beyond the curve of the jaw margin to give the associated hummocky condition. X-rays of the fossil provided by T. Rich (Museum of Victoria) are included for comparison (Fig. 6C-D). From this we conclude that the Coimadai *P. parvus* was not a juvenile, yet compared with the dimensions given by Merrilees (1967; and Table 1), it falls within the range of values for juveniles of *V. hirsutus*. (The cheektooth row length, from the anterior alveolus of P_4 to the posterior of M_4, of the four smallest female juveniles in Merrilees' sample of *V. hirsutus*, from his graphs, is 29.4, c.38, c.41 and 41 + mm. For FMNH 123652 the value is 35.6mm, and for the *P. parvus* fossil it is 37.5mm.) Thus it does not appear to be a normal variant of that taxon. Additional evidence that this *P. parvus* specimen was not a juvenile comes from four other adult, or at least more mature, conditions that it possesses: 1) The masseteric fossa is a deep pocket (Fig. 6A), not just a shallow indentation (Fig. 6B) as is seen in juveniles before growth and/or extensive chewing gives rise to the adult form; 2) The incisor tooth is relatively deep in its cross section (again compare

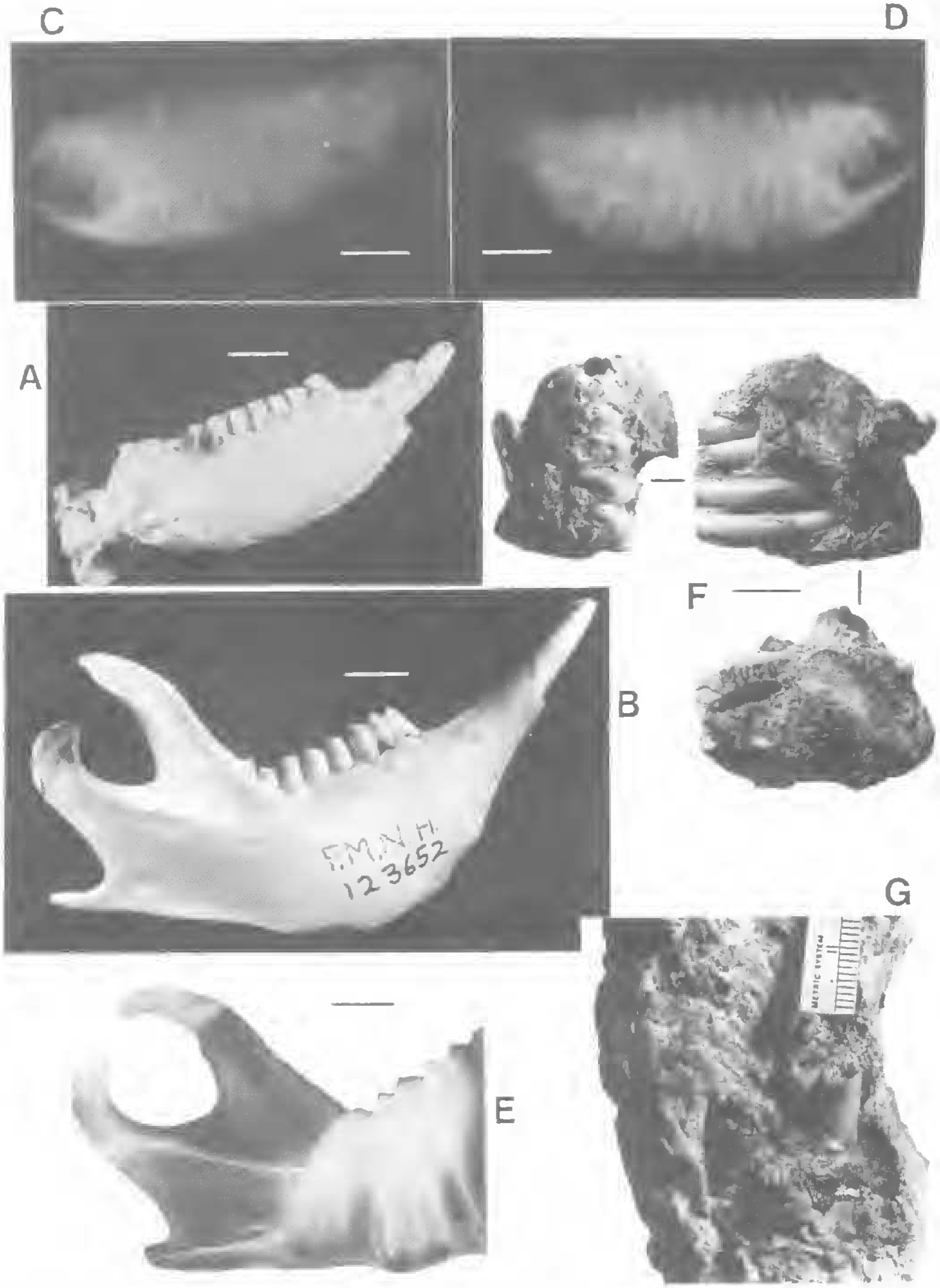

FIG. 6. Three Coimadai fossil wombat specimens, and very young juvenile of the modern *Vombatus hirsutus*. A, buccal side of right mandible, MUGD 1671, which de Vis (1898) identified as *Phascolomys parvus*. B, corresponding view of FMNH 123652, very young juvenile of *V. hirsutus*. C-E, X-rays of same specimens (at nearly the same scale) to show features discussed in text. F, G, specimens referred to cf. *V. hirsutus* (MUGD 3570 and NMV P23219 respectively). Scale = 2 cm.

A & B of Fig. 6); 3) All cheek teeth are decidedly tapered from their forming bases to the occlusal surfaces in juveniles, especially in the latter area, but the fossil shows only very slight tapering (Fig. 6A-D); and 4) seen in side view, the cheek teeth of the fossil all are truncated by wear at their occlusal ends so that a flat, nearly straight, horizontal surface has resulted. In the juvenile, although most details of the initial crown structure quickly wear away, a vestige remains in that there is a right-angled groove between the anterior and posterior moieties of each molar (even M_3 has a notch), as well as a groove between adjacent teeth (Fig. 6A & B) so that the whole occlusal surface has many angles to it and is not reduced to a flat planar surface.

From this it is clear that at Coimadai at least, the "*P. parvus*" specimen represents a species of *Vombatus* other than *V. hirsutus*. For a conclusive decision it will be necessary to examine a large series of modern juvenile wombats of both *Lasiorhinus latifrons* and again to compare directly the Coimadai specimen with Owen's holotype of *P. parvus*. We tentatively accept Merrilees' (1967) assignment of the holotype of *P. parvus* to the genus *Vombatus*, but leave the decision as to its specific assignment open, for *parvus* may yet prove to be a dwarf species of *Vombatus*.

The other three wombat specimens are teeth that are well within the size range of modern adult *V. hirsutus*. MUGD 3570 consists of M_3-M_4 and the impression of the M_2. Without any clear-cut diagnostic features, size and Merrilees' criterion of greater angulation of the outline of molar occlusal surface suggest assignment to *V. hirsutus*. Antero-posterior and posterior width measurements are given in Table 1 and the specimen is illustrated (Fig. 6F).

TABLE 1. Dental and mandibular measurements of Coimadai vombatids and of a modern specimen of *Vombatus hirsutus*. All measurements in mm.

	MUGD 3570 cf. *V. hirsutus*	MUGD 1671 '*Phascolomys parvus*'	FMNH 123652 *V. hirsutus*
Diastema L. (I-P_4)	—	>13.5	19.9
P_3 L.	—	3.5	3.2
W.	—	2.4	2.2
M_1 L.	—	6.5	5.5
W.	—	4.0	3.7
M_2 L.	—	7.0	7.0
W.	—	4.2	4.3
M_3 L.	9.3	7.5	6.7
W.	6.2	4.3	4.2
M_4 L.	7.9	5.8	5.6
W.	3.9	3.3	3.0

The last two specimens are listed as cf. *Vombatus* sp., probably *V. hirsutus*. MUGD 3585 consists of four associated fragments, two of which join, but we do not know which teeth they are. NMV P23219 is an isolated tooth, probably a lower molar, still partly encased in its travertine matrix (Fig. 6G) its antero-posterior measurement is 10.8 mm and its height from occlusual surface to the broken edge near its forming end is 31.1 mm.

Family MACROPODIDAE
Subfamily MACROPODINAE
Kurrabi sp.

MATERIAL

MUGD 3567, NMV P23160, 23218, and 186806.

DESCRIPTION

Two of the most complete and best-preserved, hence most informative specimens, MUGD 3567 and NMV P186806, are left mandibular rami which seem to represent the same species (Fig. 7A, B). They differ in ontogenetic age, and possibly sex. The older of the two (NMV P186806) has a longer diastema, but in size of ramus, position of mental foramen and length of tooth row, the two are nearly identical. MUGD 3567 is the more informative specimen, although enamel (actually an epoxy cast of the natural mould) is retained only on the M_2 talonid, the M_3 and the M_4 talonid. In size and morphology the best match is with *Kurrabi merriwaensis*. The smaller P_3 has the charactcristic form of *Kurrabi*, first described from the Bow Local Fauna, New South Wales (Flannery & Archer, 1984). It seems lower-crowned than *K. merriwaensis*, more like the Hamilton form (Flannery, pers. comm., 1988), although it is hard to evaluate with so little enamel remaining. From the description of *K. merriwaensis*, the Coimadai specimens agree with that taxon, even to details such as the shallow concavity on the posterior side of the hypolophid lingual to the midline. *Macropus dryas* also occurs in the Bow Local Fauna and, although comparable in size to *Kurrabi* sp., the dentition is higher-crowned and has better-developed links. Table 2 gives measurements for the teeth of the Coimadai specimens of *Kurrabi* sp. compared with those of *K. merriwaensis* and

FIG. 7. Three left rami of *Kurrabi* sp. from the Coimadai Local Fauna, each in (stereo) occlusal view. A, MUGD 3567, with all cheek-teeth, also shown in buccal view. B, NMV P186806, with parts of all cheek-teeth. C, NMV P23160, edentulous fragment with much of symphysis and alveoli of P_3-M_3. Scale = 2 cm.

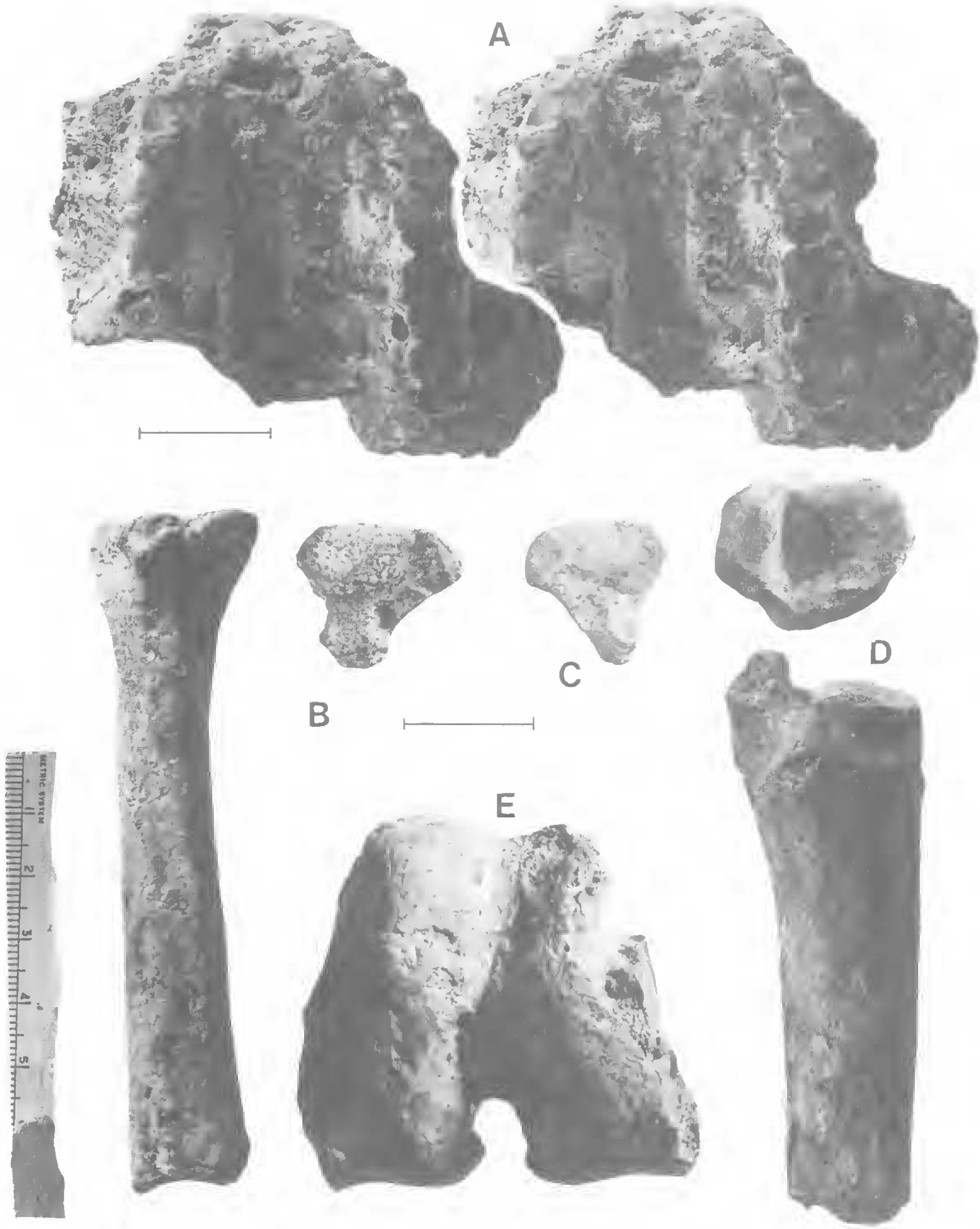

FIG. 8. Five Coimadai specimens referred to *Kurrabi* sp. A, NMV P23218, palate lacking crowns of all teeth, but with some of roots and crown-bases cast from remnants of the natural moulds; in ventral (stereo) view. B, NMV P23187, proximal two-thirds of right metatarsal IV, in ventral and proximal views. C, MUGD 3576, proximal articular end of left metatarsal IV. D, MUGD 3578, distal end and posterior views of partial left tibia. E, MUGD 3562, distal end-view of partial right femur (see also Fig. 9A). Scale = 2 cm.

TABLE 2. Dental and mandibular measurements of Coimadai and other macropodids. All measurements in mm. Measurements of tooth width were taken at posterior of tooth. Symbols: a, measurement of alveolus; b, measurement of dentine core; e, estimated; r, measurement of roots. *Kurrabi* sp., specimen NMV P23160, may comprise P_2-M_2 rather than P_3-M_3; ranges for *Macropus dryas* from Bartholomai, 1975 (T 21, Chinchilla) and 1978 (T 8, Bluff Downs); ranges for *K. merriwaensis* from Flannery & Archer, 1984 (Bow Local Fauna); measurements for *Troposodon* sp. include P_2 in place of P_3.

	MUGD 3567	NMV P 186806	NMV P 23160	NMV P 23208	T3	T21	T8	MUGD 3568	MUGD 3571	MUGD 3573	NMV P 186781	NMV P 23199	MUGD 3569
P_3 Length	11.3	10.5ᵃ	10.0ᵃ	~10.5ᵈ	10.2-11.2	10.2-11.7	10.5-11.7	11.2ᵈ	~14.5	14.0ᵃᵉ	~14.1ᵈ	—	~12.0ᵃ
P_3 Width	3.8ᵈ	3.0ᵃ	3.0ᵃ	3.0ᵃʳ	—	3.6-4.2	3.6-4.2	3.9ᵃ	5.4	—	6.0ᵈ	—	4.2ᵈ
M_2 Length	9.0	8.0ᵃ	~7.0ᵃ	9.8ᵈ	8.1-10.4	9.7-11.4	8.7-9.9	8.8ʳ	~7.3	9.0ᵃᵉ	7.5ᵈ	—	~7.7ᵈ
M_2 Width	~6.5	~6.0ᵈ	5.5ᵃ	6.9ᵈ	—	—	—	—	—	—	7.3ᵈ	—	—
M_3 Length	10.0	9.6ᵃᵈ	~9.0ᵃ	9.9ᵈ	9.0-9.9	10.4-12.7	10.0-12.5	9.8ʳ	~11.0	11.0ᵃ	10.0ᵃ	9.5ᵃ	8.6ᵈ
M_3 Width	7.6	6.9ᵈ	8.8ᵃ	8.5ᵈ	—	—	—	—	—	—	8.1ᵈ	7.0ᵃ	7.2ᵈ
M_4 Length	11.2	10.9ᵃ	—	12.3ᵈ	10.2-10.9	11.9-14.0	12.2-13.6	10.5ʳ	13.9	11.4ᵃ	12.9ᵈ	11.2ᵃ	12.5ᵃ
M_4 Width	8.7	7.8ᵈ	—	9.8ᵈ	—	—	—	—	8.7	7.3ᵃ	8.1ᵈ	8.3ᵃ	8.1ᵃ
M_5 Length	11.5	12.0ᵃ	—	12.5ᵈ	11.8-11.9	13.8-15.7	13.4-13.8	11.8ʳ	—	11.0ᵃʳ	12.5ᵈ	14.3ᵃ	12.0ᵃ
M_5 Width	7.8	6.5ᵈʳ	—	9.6ᵈ	—	—	—	—	—	—	7.9ᵈ	~8.4ᵃ	8.1ᵃ
Diastema I-P_3	~30.0	43.6	29.4	—	—	—	—	~26.0	—	—	~24.0	—	—

Macropus dryas (two samples of the latter taxon reported by Bartholomai 1975, 1978). If NMV P23160, a left ramus fragment with broken incisor and alveoli of three cheek teeth (Fig. 7C), is interpreted correctly as representing P_3-M_3 (there is no bulge in the ramus beneath the anterior teeth for a forming P_3) then it compares well with MUGD 3567 and can also be identified as *Kurrabi* sp. NMV P23218 is a palate with roots only of the right M^2-M^3 and the left P^3-M^5 (Fig. 8A). The palate extends posteriorly to opposite the anterior root of M^4, and the narial incision must be located behind this point. The palate is wide (31.6 mm at M_2) and the tooth rows do not converge markedly to the anterior. The palatine foramen lies opposite the anterior root of M^5 and the root of the zygoma is opposite M^4-M^5. P^3 is not as wide as M^2. The small size of P^3 relative to the molars suggests that this is a palate of *Kurrabi* rather than *Protemnodon.*

cf. **Kurrabi** sp.

MATERIAL

MUGD 3561-2, 3575-6, 3578: NMV P23161, P23187, and P186791.

DESCRIPTION

These specimens are all postcranial pieces assigned only tentatively to the genus. They probably belong to the same undetermined species as the previously listed cranial fragments. It is possible that they represent other genera not recognized from the cranial materials (*Halmaturus* sp., *Macropus dryas, Prionotemnus palankarinnicus).* Since the appropriately-sized cranial specimens all appear to be *Kurrabi* sp. we think this tentative assignment is the most probable of the alternatives. MUGD 3561 is the distal end of a left femur, consisting of little more than the condyles. An old label reads *Halmaturus anak* Owen. It is of a size appropriate for *Kurrabi.* MUGD 3562 is the distal end of a right femur with an old label reading *H. dryas* de Vis. It too is of a size appropriate to *Kurrabi*, or *Macropus dryas*, (Figs 8E, 9A). MUGD 3575 is a complete left metatarsal IV; shown in Fig. 14C, it measures 123.8 mm in length. MUGD 3576 is the proximal end of a left metatarsal IV (Fig. 8C) and NMV P23187 is the proximal end of a right metatarsal IV (Fig. 8B). These three examples of metatarsal IV also seem to be of a size appropriate for *Kurrabi.* They are smaller than those we refer to cf. *Macropus* sp. (below) and their proximal articular surfaces are triangular in shape, indicative of a strong metatarsal V. A left metatarsal V, lacking distal epiphysis, NMV P23161, is of suitable size (Fig. 11E). These bones are about the size of *Prionotemnus palankarinnicus* Stirton (1955) and thus could also be *Kurrabi* sp., as could MUGD 3578, the distal end of a left tibia (Fig. 8D). NMV P186791 is a part of a right pelvis with the acetabulum and base of the ilium (Fig. 9B). It has a macropodine form with a large pectineal process, and is of a size appropriate to *Kurrabi*

Protemnodon sp.

MATERIAL

MUGD 3568, 3571, 3573, NMV P186781.

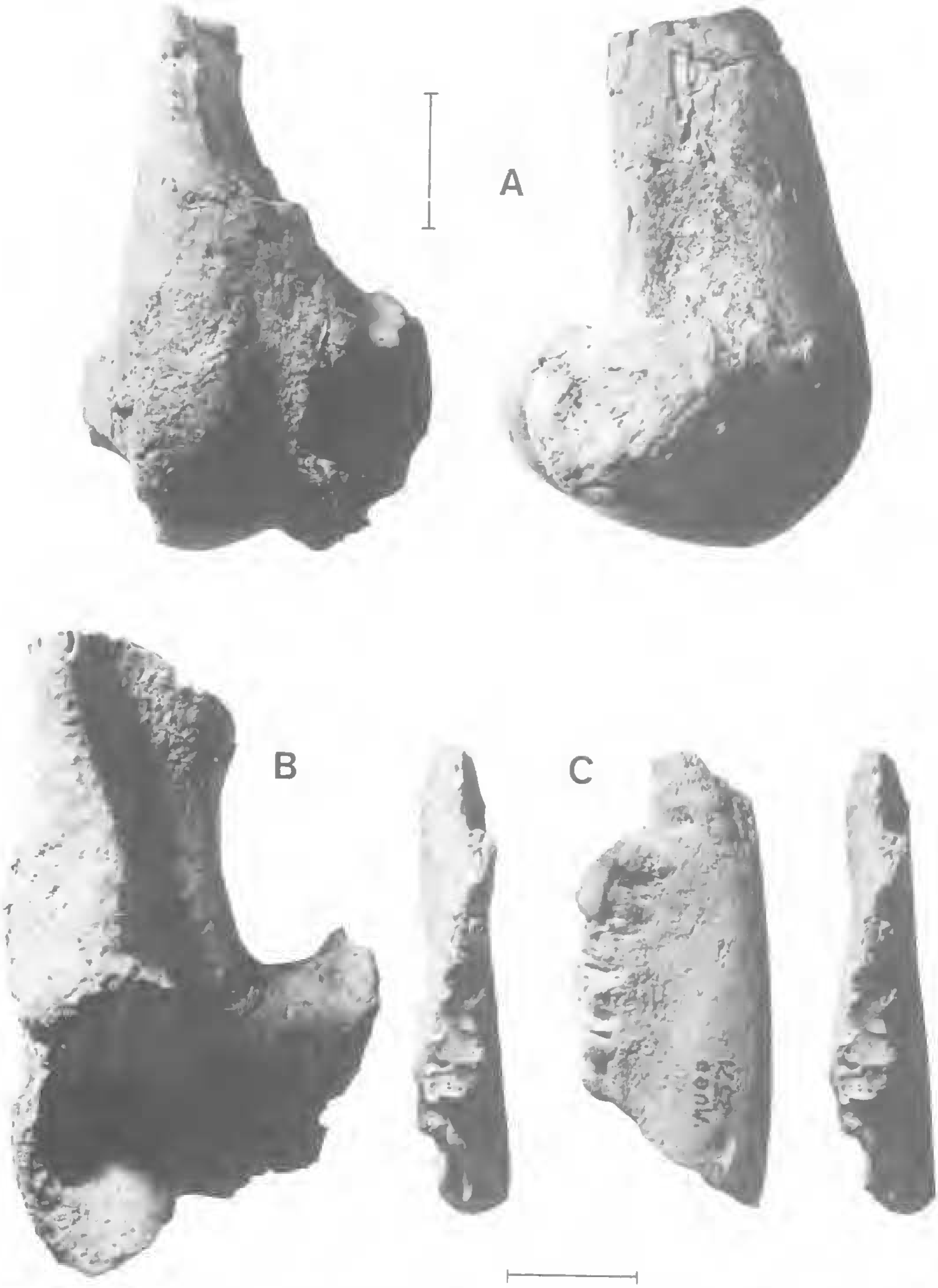

FIG. 9. Coimadai specimens referred to *Kurrabi* sp., cf. *Kurrabi*, and *Protemnodon* sp. respectively. A, MUGD 3562, distal end of right femur in dorsal and lateral views (see also Fig. 8E). B, NMV P186791, fragm ent of pelvis showing view into the right acetabulum. C, *Protemnodon* sp., MUGD 3571, a fragmentary right ramus with P_3-M_4; shown in occlusal (stereo) and buccal views. Scale = 2 cm.

Description

These four ramus fragments are slightly larger than those described for *Kurrabi* and *Troposodon minor*. MUGD 3568 is an edentulous right ramus with alveoli showing that P_3 was relatively elongate and that the molars were of appropriate proportions for the genus. The buccal groove of the jaw was distinct and long. Only a few alveolar measurements could be taken (Table 2). MUGD 3571 has the dentine cores of the right P_3, M_2-M_4 preserved (Fig. 9C). MUGD 3573 (Fig. 10B) is edentulous, with alveoli for the left P_3, M_2-M_5. NMV P186781 is a right ramus with dentine cores of P_3, M_2-M_4 (Fig. 10D). They correspond reasonably well with *P. chinchillaensis* in size, relative length of P_3 (Table 2), position of mental foramen and length of buccal mandibular groove (from posterior root of P_3 to posterior root of M_3 or anterior root of M_4).

cf. **Macropus** sp.

Material

MUGD 1476, 3560A&B, 3563-4, 3574, 3577, 3579, NMV P23165-6, P23178-9, P23189(T), P23196-7, P23199, P186782, P186784, P186786 and P186794.

Description

A number of fragmentary bones and some associated materials all seem to represent a macropodine kangaroo about the size and morphology of the living *M. giganteus* or the extinct *M. titan*. They surely represent a derived macropodine. The most informative bone is a complete left metatarsal IV,NMV P186794, 171.4 mm in length (Fig. 14B). The proximal end of another left metatarsal IV,MUGD 3574, is nearly identical in size, as is NMV P23189(T), a vug that preserved the form of the proximal end of a metatarsal IV. MUGD 1476, the proximal two-thirds of a right femur, was presented by R.J. Alkemade in 1933 and identified by E.S. Hills the same year as *Macropus* sp. (Fig. 11C). MUGD 3564 is the shaft and part of the cnemial crest of a left tibia (Fig. 11B). MUGD 3563 and 3577 are distal ends of left femora, the latter with a relatively large medial malleolus. MUGD 3560 is the articulated partial left forelimb (Fig. 11A), with much of each long bone preserved as natural moulds.

NMV P23197 consists of both articulated partial forelimbs preserved in two apparently associated concretions, every bone preserved as a vug. Now epoxy-filled, the left elements are the distal halves of the radius and ulna, the carpals, metacarpals II-V, some of the phalanges and several sesamoids; the right elements are the distal epiphyses of radius and ulna, the carpals and metacarpals II-V, proximal phalanges of digits II-IV and some other phalanges and at least 6 sesamoids. Fig. 12 shows the partial left forelimb in dorsal aspect and the right manus in palmar aspect. Correspondence to forelimb and manus of *Macropus* is fair. MUGD 3579 is a part of a large pelvis with massive bone but a relatively small acetabulum. NMV P23165-6 are scapular fragments that may belong together, but if so the contact has been lost. NMV P23178 (Fig. 14D) and P23196 each consist of the mid and distal portions of the shaft of a humerus preserving part of the deltoid ridge and the entepicondylar foramen. NMV P23179, a concretion with several vugs seeming to represent a terminal phalanx and parts of astragalus and calcaneum. NMV P186782 is another hollow (natural mould with most of the bone gone); now epoxy-filled and prepared, it is the distal end of a tibia with a poorly-preserved epiphysis. NMV P186784 and P186786 are also pieces of tibial shafts, the first about 18 cm long, the other 14 cm long. The only jaw fragment tentatively referable to *Macropus* is an edentulous left ramus, NMV P23199 (Fig. 14A), with alveoli for M_3-M_5. The strong molar size gradient and increasing jaw depth anteriorly support this identification.

Subfamily STHENURINAE
cf. **Troposodon** sp.

MUGD 3569, a nearly complete edentulous left ramus with dentine cores, roots or alveoli is here interpreted as representing P_2, M_1-M_5 (Fig. 10B, Table 2). The dental formula, showing eruption of M_5 before P_3, is typical of sthenurines. The crest of P_2 is lingually directed and the specimen is about the size of *T. minor*. It is referred to *Troposodon* because the jaw is relatively shallow beneath M_4-M_5; the symphysis procumbent and the mandible, although wide at M_4-M_5, is not as robust throughout as in *Sthenurus*. It is slightly larger than the specimens here assigned to *Protemnodon*; the cheek-tooth row is longer (in spite of a shorter premolar) and the last two molars are larger and somewhat more massive.

MACROPODIDAE gen. et sp. indet.

Material

MUGD 3565-6, 3580-1, NMV P23162, P23164, P23170, P23181, P23188, P23194-5, P186783,

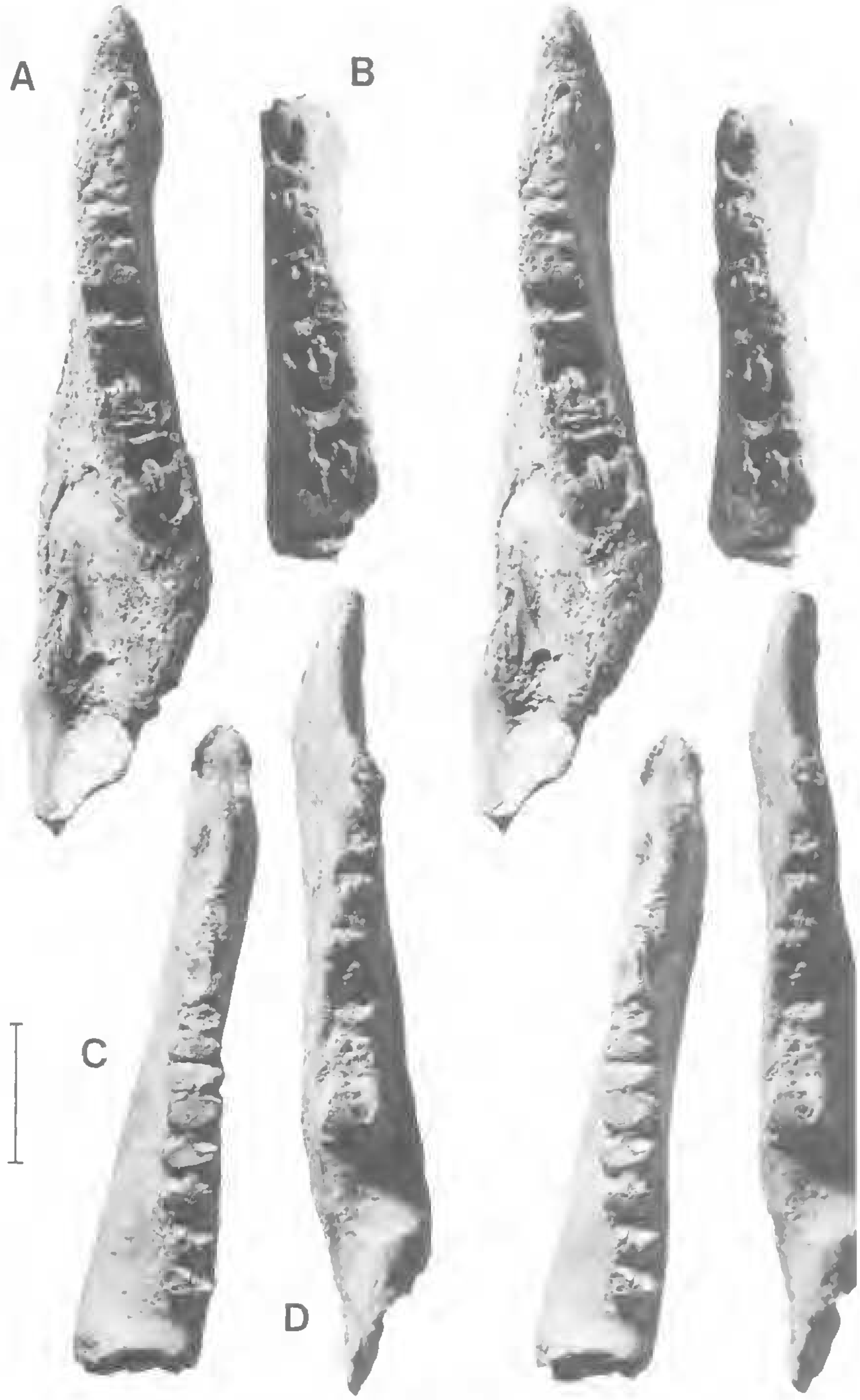

FIG. 10. Four of the Coimadai jaw rami referred to *Troposodon* sp. (A), and to *Protemnodon* sp. (B-D), all in (stereo) occlusal view. A, MUGD 3569, left ramus with parts of P_3-M_3 and alveoli of M_4-M_5. B, MUGD 3573, an edentulous left ramus fragment with alveoli of P_3-M_4. C, NMV P186781, a left ramus with part of P_3 and most of M_2-M_5. D, MUGD 3568, an edentulous right ramus with alveoli of cheek-teeth. Scale = 2 cm.

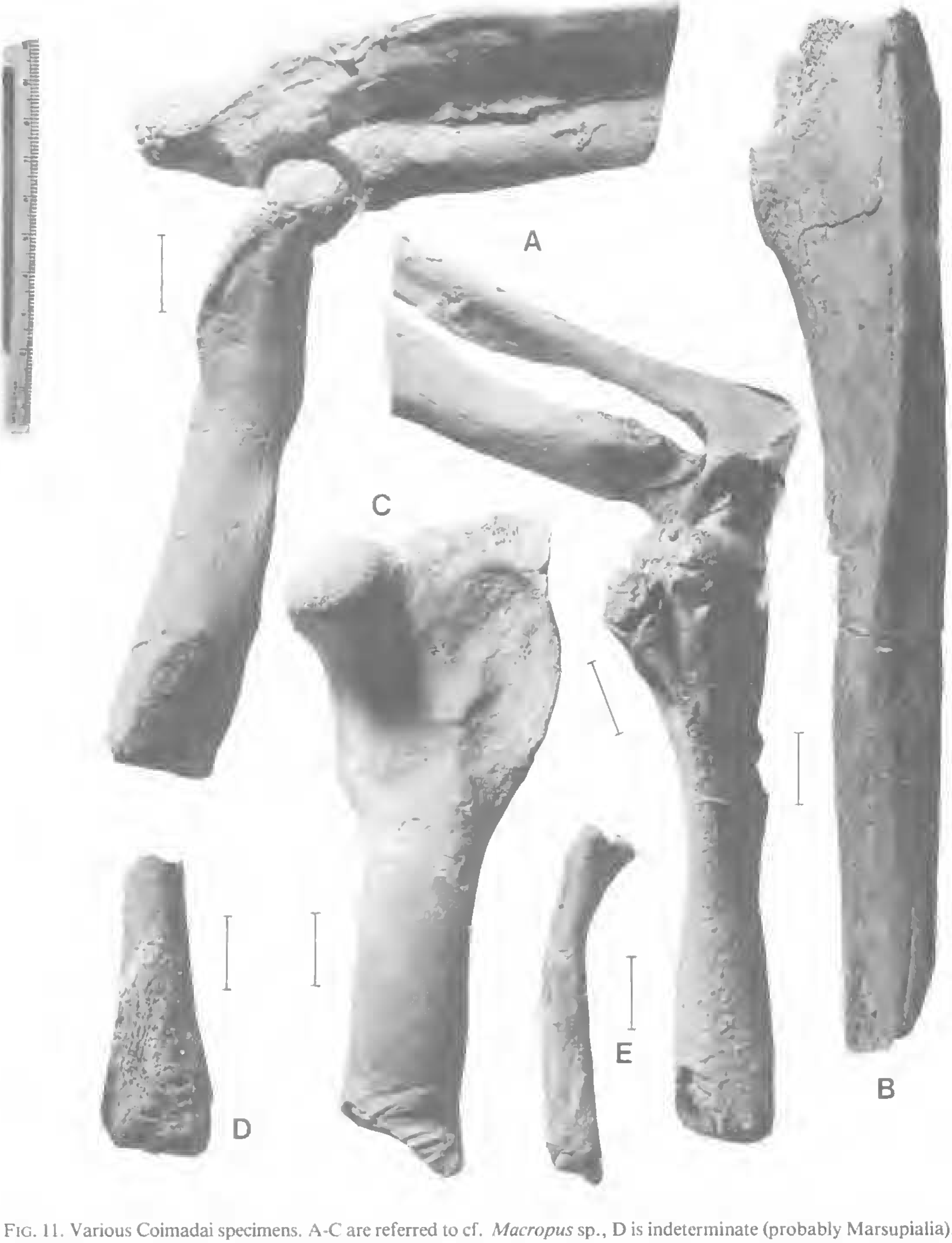

FIG. 11. Various Coimadai specimens. A-C are referred to cf. *Macropus* sp., D is indeterminate (probably Marsupialia), and E is referred to *Kurrabi* sp. A, MUGD 3560, casts of articulated partial left forelimb, taken from natural moulds. B, MUGD 3564, proximal two-thirds of left tibia, showing cnemial crest. C, MUGD 1476, proximal two-thirds of right femur, in posterior view. D, NMV P23183- 4, joined fragments of fragile medullary trabeculae from a long bone; all the dense compacta bone has been destroyed. E, NMV P23161, a stout left metatarsal V, which articulates almost perfectly with another *Kurrabi* specimen (MUGD 3575). Scale = 2 cm.

FIG. 12. Articulated partial front limbs of NMV P23197, cf. *Macropus* sp.; preserved as hollow natural moulds that are now epoxy-filled and prepared in relief on their matrix base (stipple). At left is the partial left forelimb in dorsal aspect; at right, the right manus in palmar aspect. Scale = 2 cm. Abbreviations and symbols: wavy lines with or without arabic numerals, openings into the vugs at the weathered surface of blocks before preparation; Roman numerals I-V, metacarpals and digits; phalanges (Ph) also shown with Roman II-IV and arabic numerals to indicate position; Cu, cuboid; Lu + Un, lunar + unciform; Mg + Td, magnum + trapezoid; Pis, pisiform; R, radius; s, sesamoid; Sc, scaphoid; Term Ph, terminal phalanx; Tz, trapezium; U, ulna.

P186789-90, P186792-3 (T), P186795, P186798, P186800, and P186802 (T).

DESCRIPTION

The first two, MUGD 3565-6, are 16-18 cm long pieces of tibial shafts. MUGD 3580-1 are two pieces of the midshaft region of longbones. MUGD 3580 had been designated as a humerus on its old label, but this is doubtful as all surface compacta is gone and only the trabecular pattern of the spongiosa remains. NMV P23162 and P23164 are both tibial midshaft bits. NMV P23170 is a 7 cm length of rib. NMV P23181 is a 6 cm long piece of the midshaft of a longbone, with its open medullary tract now epoxy-filled. It could be a piece of femur, tibia, or humerus. NMV P23188 is the distal end of a fibula. NMV P23194-5 are two femoral midshaft pieces, each preserving some of the bicipital tuberosity. NMV P186783 consists of two bones: number 2 is the proximal end of the shaft of a large left femur with part of the lesser trochanter and the bicipital tubercle; and number 2A is a bit of the shaft of a tibia. The associated label specifies *Halmaturus dryas*, but this is doubtful. They could be from a large *Macropus* or a *Protemnodon*. NMV P186789 is the proximal two-thirds of the shaft of a right humerus, from the epiphysis to beyond the deltoid crest at about the narrowest point of the shaft. NMV P186790 (T) is the distal third of a large left femur (Fig. 14E). It includes most of the shaft distal to the bicipital tuberosity but is lacking the distal extremity and the condyles. All surface bone is gone, but the trabeculae within (and the plaster-filled medullary tract) show the supracondyloid fossa and the raised bony shelf that led to the condyles. NMV P186792 (T) and P186793 are two distal ends of tibial shafts. The first was a hollow 10 cm long that was plaster-filled and prepared, but that early attempt to save the bone was not successful (Fig. 13C). A better procedure would be to sacrifice the bone and to cast from the natural mould. NMV P186795 is from the midshaft of a long bone whose sections suggest that it may be an ulna. NMV P186798 consists of two joined pieces of rib. NMV P186800 and P186802 (T) are both midshaft pieces of large diameter long bones, probably femora, the latter with very leached, punky bone with questionable indication of the bicipital tuberosity. NMV P186801 is a bit of the proximal end of the shaft of a tibia.

Family DIPROTODONTIDAE
Subfamily DIPROTODONTINAE
Euowenia sp.

NMV P23202-3 are both edentulous rami which belong to the same mandible and show the whole tooth row, parts of the symphysis and ascending ramus (Fig. 13A). Comparative measurements (Table 3) show that NMV P23202-3 is similar in size to the Late Miocene *Pyramios alcootensis* and to the Pliocene *Meniscotherium mawsoni* and *Euowenia grata*. Like those of *Pyramios* and *Euowenia*, the mandible is deep, particularly at the posterior end of the symphysis, and tapers markedly to the rear. The symphysis does not extend behind the anterior part of M_2, as in *Euowenia* and *Pyramios* and unlike *Meniscotherium* or *Nototherium*, which have long symphyses (extending to the anterior part of M_2 in *Meniscotherium* or M_3 in *Nototherium)*. The posterior end of M_5 in the Coimadai specimen is not significantly overlapped by the edge of the ascending ramus, as in *Pyramios*, not as in the other genera. The posterior opening of the dental canal lies at the end of a long post-alveolar crest, above the alveolar border and probably above the crowns

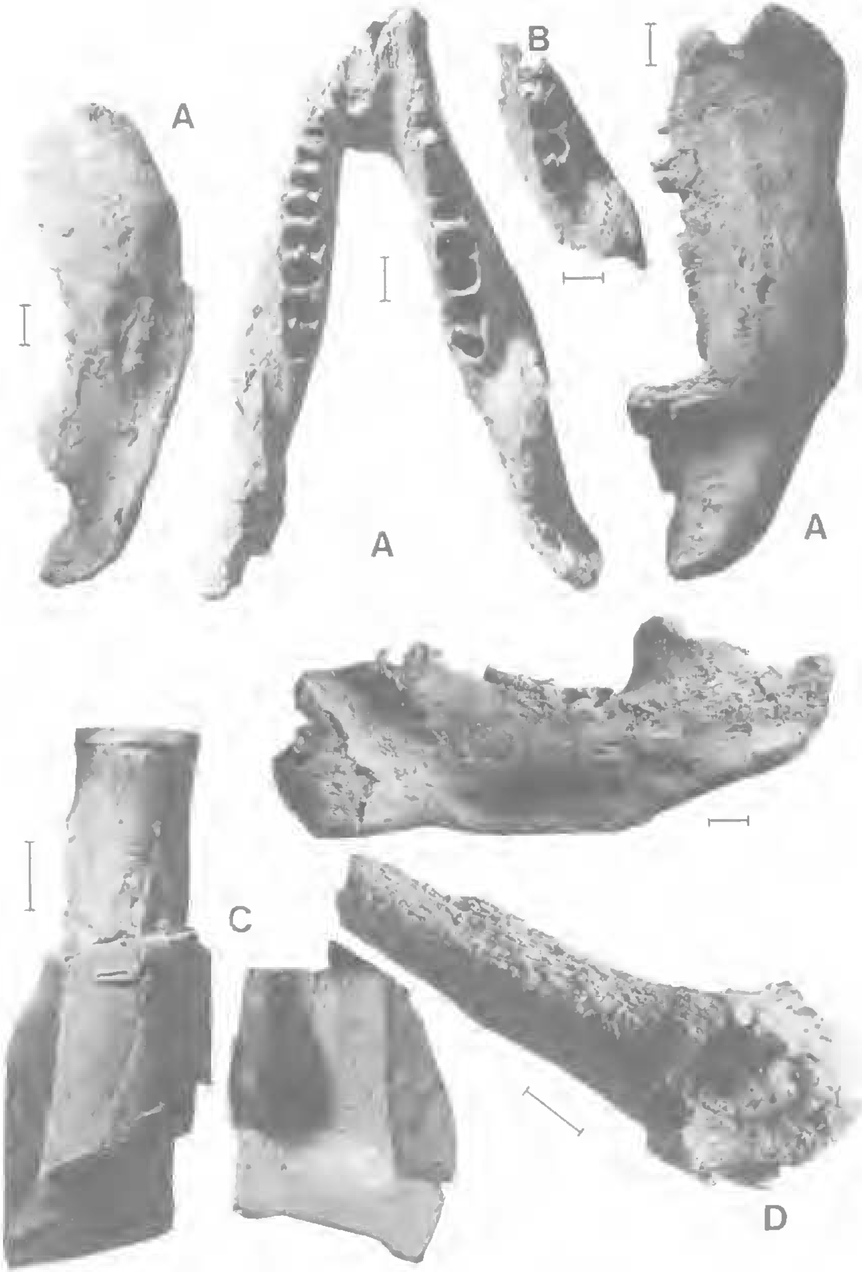

FIG. 13. Two of the Coimadai diprotodontid specimens (A, B), and indeterminate pieces (C, D) that illustrate preparation problems and two common styles of preservation. A, *Euowenia* sp., NMV P23202-3; nearly edentulous pair of jaws, associated but without contact, shown in dorsal and lingual views; the right ramus is also shown in buccal view. B, NMV P23198; edentulous jaw fragment identified as cf. *Zygomaturus;* evidently with a broad talonid to M_5, to judge from comparison with the alveolus of M_5 in *Euowenia,* fig. 13A. C, NMV P186792, part of the shaft of a long bone identified as cf. indet. macropodid; used to determine the best means of preparation when a hollow concretion contained fragile bone around the void. It was plaster-filled and the upper half prepared as usual. For the lower half the bone of one side was sacrificed and a cast of the exposed natural mould proved to be the best means of obtaining the bone's surface detail. D, NMV P23200, indet. vertebrate, probably Marsupialia; another specimen of taphonomic interest in that all dense bone has been resorbed, leaving only the spongiosa and some of the inner trabeculae of the compacta. Scale = 2 cm.

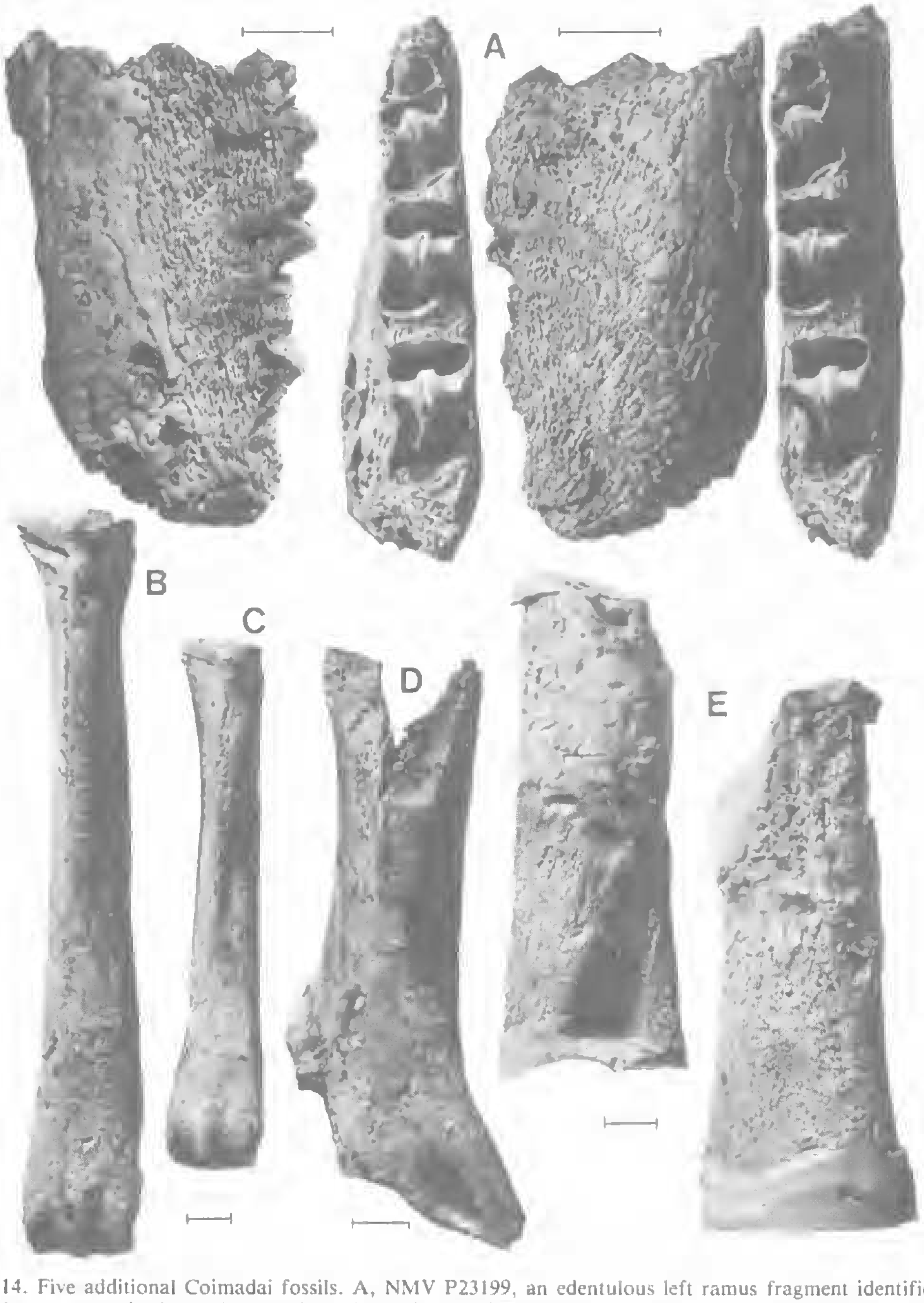

FIG 14. Five additional Coimadai fossils. A, NMV P23199, an edentulous left ramus fragment identified as cf. *Macropus* sp., in dorsal (stereo), buccal and lingual views. It shows a condition commonly seen in Coimadai materials, where all tooth tissues and dense surface bone are gone, leaving the trabecular bone matrix pattern. B, NMV P186794, complete left metatarsal IV identified as cf. *Macropus* sp., in postero-ventral view. C, MUGD 3575, *Kurrabi* sp., complete left metatarsal IV, also in postero-ventral view. C, NMV P23178, cf. *Macropus* sp., a partial right humerus in antero-dorsal view. E, NMV P186790, a heavily-leached piece of macropodid femur, prepared by filling the open medulla with plaster and removing the superficial matrix. Little of the original compacta remains, but the overall shape is sufficient to permit identification of the large supracondyloid fossa. Scale = 1 cm.

of the teeth as in *Nototherium*, not at or below this level as in *Euowenia*, *Meniscotherium* or *Pyramios*. The digastric process on the inferior border of the ramus lies just behind M_5 as in *Euowenia*, *Pyramios* and *Meniscotherium*, rather than markedly behind as in *Nototherium*. The symphysis is fused, its shape at mid-suture being oval with the long axis at about 40° to the alveolar border of the cheek teeth, as in *Euowenia*. There is a lower gradient in *Pyramios*, *Nototherium* and *Meniscotherium*. The lower incisor root is very large, as in *Euowenia*. It is directed at a low angle to the alveolar plane at this level but it probably curves dorsally as in *Euowenia* for the I_1-P_3 distance cannot be much over 70 mm, as in *Euowenia* (113 in *Meniscotherium*: 99-130 in *Pyramios*). The incisor alveoli indicate the roots to be widely open, not tapering significantly posteriorly as in *Pyramios* and not reaching the anterior root of P_3 as in *Euowenia*, *Nototherium* and *Pyramios*. The incisor cross-section shows an internal ridge delimited by two sharp grooves apparently as in *Euowenia*, but not the other genera. The alveoli of the cheek teeth show a strong gradient in length extending to M_4, the longest tooth, as in the other genera compared. The posterior root of the M_4 has a lower inter-radicular crest than the anterior and is narrower transversely indicating a markedly narrower talonid for this tooth as in *Euowenia*. The conclusion reached from these comparisons is that the Coimadai mandible is a diprotodontine diprotodontid, sufficiently resembling *Euowenia* in mandibular form to be assigned to that genus.

Subfamily ZYGOMATURINAE
cf. **Zygomaturus** sp.

Another diprotodontid, probably a zygomaturine, is indicated by NMV P23198, an edentulous fragment of a right ramus showing alveoli for M_4-M_5. The mandible is wider than that attributed to *Euowenia*, and the M_5, judging from its alveoli, is slightly shorter than M_4 and had a talonid as wide as the trigonid (Fig. 13B).

DIPROTODONTIDAE
Genus indeterminate

One specimen, NMV P23214, is so assigned on the basis of its large size. It probably is the proximal

TABLE 3. Dental and mandibular measurements of selected diprotodontids in comparison with the Coimadai *Euowenia* specimen. All measurements in mm. Includes data from de Vis, 1887 *(Euowenia grata)*; Stirton, 1955 *(Meniscolophus mawsoni)*; Woodburne, 1967, tables 4-6 *(Pyriamos alcootensis)*.

	cf. *Euowenia* NMV P23202-3	topotypes *Pyriamos alcootensis*	*Meniscolophus mawsoni*	*Euowenia grata*
Length P_3	~15 alv.	13.5-15.4	17.2	14.5
Length M_2	~18 alv.	20.9-21.2	29.0	—
Length M_3	~25 alv.	24.4-29.7	32.4	—
Length M_4	~32 alv.	27.2-36.1	36.4	34.5
Length M_5	~32 alv.	30.1-35.8	37.1	—
Incisor Length	~37	20.7-28.9	—	32.0
Incisor Width	26	9.4-13.1	—	26.5
Mandible depth				
at P_3	~93	—	—	105.5
at M_2	~86	67.1-95.6	70.0	—
at M_4	~80	63.6a-95.5	61.0	—
Mandible length from rear of symphysis to digastric process	~135	121.2	—	—
Mandible length P_3-M_5	~123	119.5-121.0	130.3	—
Mandible length M_2-M_5	~116	—	133.4	135.5

end of a left femur lacking the head and trochanters, but conceivably could be the proximal end of a tibia or humerus.

Indeterminate vertebrate remains

Nearly half the specimens fall into this category. We have identified them as closely as possible; many are of taphonomic significance, the most important being indicated in the listings with the code-letter (T) — as was done also with some of the more definitively assigned specimens above.

MATERIAL

Australian Museum F1236, MUGD 3582-4, NMV P23163, P23167-9(T), P23171-5(T)-7, P23182-4(T) (Pl. IX D), P23190-1, P23193, P23200(T) (Pl. X D)-1(T), P23215, P186785, P186787-8, P186796, P186799(T), and P186803-5. All are either mere bone scraps with no diagnostic features, or they are so leached and eroded that we assign them as ? Mammalia, probably Marsupialia.

Two large-diameter rib pieces now joined, NMV P23180 and P23192, suggest a pachyostotic condition somewhat like that seen in ribs of dugongs, although it is not nearly as well-developed. They are of an appropriate size for a dugong, but more probably are pieces of a small diprotodont.

One macropodid ramus with 2½ teeth (?M_2-M_4), MUGD 3572, we suspect is not from any of the Coimadai quarries. Its preservation is different from all of the others, resembling more that at Lake Colongulac.

A final lot of specimens are all concretions, some with faint traces of bone that could represent nuclei, but most show no trace of bone or any other nucleating source. These are: NMV P23185-6, P23204-13 and P23216-7.

TAPHONOMY

The generally poor state of preservation of tooth and bone at Coimadai deserves attention. Usually the hardest and most resistant vertebrate tissues persist the longest. This is not so in this situation, where tooth enamel succumbs first (Figs 7A-C, 10A-D) to whatever diagenetic or other destructive agents are operating, then dentine (Fig. 10A,C), then dense bone such as compacta, leaving only the most fragile-appearing bony materials as final remnants — the medullary trabeculae of the spongiosa (Fig. 14A) and the trabecular groundmass pattern of internal bone fabric (Figs 13D, 14E). Finally all trace of the original tissues disappear and only empty limestone or lime-mud hollows remain (Figs 11A, 12), natural moulds of the original exterior surfaces. There are exceptions to this usual sequence of destruction, especially when subaerial surface weathering persists for long periods. Behrensmeyer (1978) has characterized six bone-weathering stages for one East African region, the Amboseli Basin. At first glance many of the Coimadai fossils appear to match the conditions she described. However, we do not think that the comparison properly applies in this case, for many of our specimens were entombed and fossilized quickly as is evidenced by the fact that some were in articulation and many of the natural moulds preserve unweathered bone surfaces in good condition. Surface weathering apparently was not the primary destructive agency involved. Instead unusual ground water chemistry seems a more likely cause.

CONCLUSIONS

Restudy of fossil material from the Coimadai limestone quarries and of the geological relationships of the quarries confirms the presence of three families of marsupials in the fauna but indicates that the age is Pliocene rather than Pleistocene as originally thought by de Vis (1898) and later by Coulson (1924). Despite the difficulties of identification posed by the unusual preservation of the Coimadai fossils, it has been possible to gain some knowledge of the more abundant taxa. There is a mixture of genera, both extant (*Vombatus*, *Macropus*) and extinct (*Kurrabi*, *Protemnodon*, *Troposodon*, *Euowenia* and *Zygomaturus*). Such mixtures are known only from post-Miocene assemblages in Australia (Woodburne *et al.*, 1985). Some of the extinct genera (e.g. *Kurrabi*, *Euowenia*) have chronological ranges restricted to the Pliocene, and the most comparable species within *Protemnodon* are also Pliocene taxa. The Coimadai Local Fauna thus seems clearly of Pliocene age and, if comparable to the Chinchilla and Bow faunas as indicated above, it probably is of Early or Middle Pliocene age. These biochronological results are in harmony with, and thus help support, the geological inferences that the lacustrine environment in which the fauna was entombed was in existence prior to disruption of the local drainage by deposition of extensive alluvial fans E of the Rowsley Fault. The uplifted, rejuvenated western side of the fault contributed the material of the fan deposits, but the stream (Bullengarook Creek) aggraded to accommodate the added material until the Bullengarook eruption filled its channel with a basalt flow (3.3 – 3.6 Ma) that formed a resistant cap. This forced development of two parallel drainage systems, one (Pyrete or Coimadai Creek) E of the old Bullengarook Creek and the other (Goodman's Creek) on its W side. The influx of detritus continued until well after the Bullengarook flow (well into the Pleistocene) before the present erosional phase became dominant. The Coimadai quarries exposed both pre- and post-Bullengarook flow deposits including the Coimadai Limestones with their fossils, the majority of which came from a few metres below the reported ash bed that Coulson (1924) correlated with the Bullengarook flow. There are a few Early Pliocene assemblages from Victoria (Rich *et al.*, 1982; Woodburne *et al.*, 1985) that likewise can be related to the dated Newer Basalt Province, or can be tied to marine strata for independent age-assessment. Some of these faunas lack systematic treatment and the best known, the Hamilton Local Fauna, of earliest Pliocene age (4.47 Na) lacks an adequate representation of comparable large forms (Turnbull & Lundelius, 1970). However, several of the same macropodid genera occur at Hamilton (*Kurrabi, Troposodon, Protemnodon*) (Flannery, pers. comm.) as at Coimadai, setting the earliest known limits to the chronological range of those taxa in Australia. The small vombatid, which has been assigned to *Phascolomys parvus* by de Vis (1898) and others, and was considered to be a juvenile assignable to *Vombatus hirsutus* by Merrilees (1967), has a number of characters that suggest that it may in fact represent a dwarf species. Further study and comparison with the type will be necessary to assess its relationships.

ACKNOWLEDGEMENTS

The late Edmund Gill of the (National) Museum of Victoria introduced two of us (ELL & WDT) to the Coimadai quarries and other potentially fossiliferous localities in 1963-4, arranged for loans and shipment of materials and helped in many other ways. Marlene Werner, Zbigniew Jastrzabski, Ronald Testa, Sophia Anastasion-Wasik and Clara L. Richardson of the Scientific Support Services Staff and/or Division

Photography of the Field Museum aided with the illustrations. William Simpson (Chief Preparator) aided Turnbull in the development of the epoxy injection technique. Moulding and casting was done by John Harris. We thank Thomas Rich for X-rays of the *Phascolomys parvus* specimen. Barrie Smith, Assistant Chief Construction Engineer on the Lake Marrimu Project, made it possible for Turnbull to revisit the Coimadai site in May 1987. The investigation at Coimadai was carried out under NSF grant GB975, with additional support from both the Field Museum and the University of Texas at Austin.

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